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New Mexico State University PH.D. 1984

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SEASONAL FOOD HABITS
OF MULE DEER
IN THE FOOTHILLS OF THE SACRAMENTO MOUNTAINS, NEW MEXICO

BY

ELFATIH ELTAGI MAHGOUB, B.S., M.S.

A Dissertation submitted to the Graduate School

in partial fulfillment of the requirements

for the Degree

Doctor of Philosophy

Major Subject: Range Science

Related Area: Wildlife Science

New Mexico State University

Las Cruces, New Mexico

August 1984

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"Seasonal Food Habits of Mule Deer in the Foothills of the Sacramento Mountains, New Mexico," a dissertation prepared by ElFatih E. Mahgoub in partial fulfillment of the requirements for the degree, Doctor of Philosophy, has been approved and accepted by the following:

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ABSTRACT

SEASONAL FOOD HABITS

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IN THE FOOTHILLS OF THE SACRAMENTO MOUNTAINS, NEW MEXICO

BY

ELFATIH ELTAGI MAHGOUB, M.S.

Doctor of Philosophy in Range Science

New Mexico State University

Las Cruces, New Mexico, 1984

Dr. Rex D. Pieper, Chairman

Studies involving habitat structure and mule deer diets were conducted on the Fort Stanton Experimental Ranch in the foothills of the Sacramento Mountains. Vegetation was sampled in three main pastures at the ranch--west, east and south. Cover and composition of browse species were determined by the line intercept method. Eight of the fifteen species sampled constituted 99% of the browse composition. Analysis of variance revealed no significant differences in cover for each species among pastures. The most important browse species included wavyleaf oak (Quercus undulata), one-seed juniper (Juniperus monosperma) and pinyon (Pinus edulis).

Herbaceous vegetation was sampled by the step-point method. Herbaceous cover was higher ($P<0.05$) in the west and south pastures than in the east pasture. The data indicated an inverse relationship between cover of woody and herbaceous plants.

Deer pellets were collected from transects randomly located in deer habitat in the three pastures during different seasons from June 1981 through September 1983. THe microhistological technique was used to determine seasonal food habits of mule deer. A randomized block design was used to analyze the data. Data averaged over all pastures and dates indicated that browse constituted nearly 80%, forbs 20% and grass less than 2% of the diet.

Important components of the diet included wavyleaf oak, juniper, mountain mahogany (Cercocarpus breviflorus), carruth sagewort (Artemisia carruthii), vervain (Verbena bipinnatifida) and scarlet globemallow (Sphaeralcea coccinea). There were no differences ($P<0.05$) for most species among years, pastures or the year x pasture interactions. However, differences ($P<0.05$) existed between spring and summer diets. Summer diets were higher ($P<0.05$) than spring diets in skunkbush (Rhus trilobata), brickellia (Brickellia grandiflora), carruth sagewort, vervain, yellow sweet clover (Melilotus officinalis), scarlet globemallow, and lower in juniper, pinyon and mountain mahogany content. Apparently other features such as topography, cover, water, etc. were more critical than food resources in determining suitable deer habitat for this area.

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INTRODUCTION

The mule deer (Odocoileus hemionus Rafinesque) is one of the most popular and important wildlife species in New Mexico. Most of this popularity has been derived from its value to sport hunters and to the increasing number of wildlife enthusiasts who wish to view wildlife in its natural habitat. These demands dictate that mule deer habitats be managed for maximum production.

The rapid growth rate of the human population and encroachment of urban development on rangelands and wildlife habitat pose a real challenge to habitat managers. Though these phenomena may be beyond their control, the ramifications of increasing demands for a decreasing habitat base are not. This necessitates managers' adopting an approach of intensive management for species richness.

Intensive species management requires greater knowledge of seasonal food and feeding habits of the species. This information is essential for habitat suitability studies in areas utilized by different animal species. It is also indispensable for managers since it aids in establishing guidelines for habitat improvement and serves as a basis for research on quantitative values of the principal food items. In range restoration, managers need to ascertain whether planted seeds and seedlings need protection before establishment.

The objectives of this study were to provide habitat managers with a description of Fort Stanton habitat and to elucidate seasonal food habits of mule deer. This information is vital for effective

habitat management and provides the foundation for effective conservation practices and wise utilization of the environment.

LITERATURE REVIEW

Habitat is the foundation on which a population exists, and is a good predictor of population health and vigor. The most important factors which affect habitat quality, quantity and use are water, food and cover.

Wood et al. (1978) observed an increase in deer density at Fort Stanton when permanent water sources were developed. These workers recommended that distance between water sources should range between 4.0 and 4.8 km. Although deer can survive on moisture from succulents, marginal conditions may permit only survival (Elder 1956).

The primary functions of cover are to provide shelter from weather, escape routes, and hiding places from predators. Cover has been divided into hiding cover, which provides security for the animal and thermal cover, which aids the animal in maintaining body temperature (Thomas et al. 1976). Special cover for fawning or calving may be necessary. Habitat managers can improve habitat through vegetation manipulation. The design of habitat modification should take into consideration the amount of area needed for hiding cover, thermal cover, food production, and the various arrangements of these areas within the vegetational matrix with the optimum amount of edge (Severson and Medina 1984).

Knowledge of food consumed by large herbivores relative to forage availability is fundamental for most management decisions concerning habitat. Accordingly, food habit studies have been conducted throughout the world. However, generalized regional

descriptions tend to have limited value for local management. Preference or selectivity by the animal is based largely on relative availability, which varies in space and time. Hence, habitat management situations often develop in which such information is lacking or outdated (Severson and Medina 1984).

Dietary Sampling Procedures

Field observations of diets in various locations have been reported through the centuries and have evolved into our present-day knowledge of food habits with its associated field and laboratory methods. One of the earliest food habit studies was conducted by Carolous Linneaus in 1734. He offered a great number of plant species to cattle, goats, horses and pigs and observed which plants were consumed and which were rejected (Tribe 1950).

Food intake, nutrient content, digestibility and botanical composition of the diet of animals grazing rangelands have been determined by direct vegetational analysis as well as by harvesting and stall-feeding to animals. Cook et al. (1948), Halls (1954), Edlefsen et al. (1960) and Hercus (1960) simulated the diet of grazing animals by field observations, mowing, clipping or hand-plucking forage believed to be similar to that selected by the animals. However, these methods do not give a reliable estimate of the range animal's diet on ranges with a complex mixture of species (Hardison et al. 1954, Edlefsen et al. 1960) due to diet selectivity, which is a complex behavioral act that is influenced by many factors (Krueger et al. 1974). The primary methods used for estimation of

dietary compositon of free-ranging herbivores are direct observation of the animal, direct measurements or estimation of utilization, fistula techniques, examination of material found in the digestive tract and fecal collection.

Direct Observation

Direct observations of an animal can provide information on food habits via feeding-minutes or bite-count techniques. Wallmo et al. (1973) determined that the feeding-minutes methods overestimated use of shrubs and underestimated use of grasses and forbs. They found that identifiability of individual species varied with plant size, distance, and observer. They ascertained that an observer would have to be within 75 ft of the animal to identify correctly 80% of the species which were being grazed. This problem can be circumvented by using tamed animals. Tame deer have been used to study food habits by McMahan (1964), Healy (1971) and Stormer and Bauer (1980). This technique allows the observer to be positioned close enough to the animal to record not only use on all plant species, but also on plant parts being consumed, and to collect specific unknowns for later identification (Severson and Medina 1984).

Utilization Techniques

Methods of quantifying food habits of wild animals by direct measurement or by estimation of utilization of plants were described by Edlefsen et al. (1960), and reviewed by Smith et al. (1963).

Methods include those based on differences before and after grazing, differences between grazed and ungrazed plots, and general observations and comparisons with predetermined standards of use. Most of these methods were developed for use with livestock. Feeding habits of wild ruminants are generally such that it is difficult to detect use by examination of the plants. Wild ruminants tend to move more during feeding and to consume less of each plant than livestock. It is also difficult to detect use of individual leaves on shrubs, certain fruits, mosses, lichens and mushrooms. When several species are using the range, it is impossible to assign use to any one species. Utilization estimates, especially when ocular, are subject to observer error and personal biases (Smith and Shandruk 1979). Data from utilization studies have shown poor agreement with data from esophageal-fistulated animals (Lesperance et al. 1960, Connor et al. 1963, Ridley et al. 1963) and with data from deer rumen contents (Smith and Shandruk 1979).

Fistula Techniques

Fistula techniques were developed so that animals could be used to collect a grazed sample of the diet, thus eliminating personal biases (Torell 1954, Lesperance et al. 1960, Free et al. 1971, Theurer et al. 1976). Esophageal and rumen fistula techniques have been used with livestock for both food habit and nutritional studies for many years. Although limited use of fistulation has been made with tame white-tailed deer, advantages of direct observations have overshadowed their use (Severson and Medina 1984). Esophageal fistula

sampling is simpler and less time-consuming than rumen fistula sampling (Theurer et al. 1976). The primary disadvantages of esophageal sampling are contamination by regurgitation of rumen contents into the collection bags (Bath et al. 1956), low precision for individual dietary species (Van Dyne and Heady 1965, Galt et al. 1969, Harniss et al. 1975, Holechek and Vavra 1983) and incomplete sample recovery (Grimes and Watkins 1965, Campbell et al. 1968).

Digestive Tract Samples

Wildlife researchers commonly analyze rumen and intestinal tract contents to estimate herbivore diets (Chippendale 1962, Chamrad and Box 1964, Korschgen 1966, Chamrad and Box 1968, Smith and Shandruk 1979). Although this method has been accepted by many investigators, quantitative analysis requires large sample size due to the great variability of rumen contents between animals (Anderson et al. 1965). It is a destructive method because sample collection requires animal sacrifice. Thus, only one sample per animal is permitted which restricts its applicability to large animal populations (Short 1966).

Fecal Samples

Fecal samples have been used for seasonal diet surveys (Hansen and Gold 1977), diet and vegetation type survey (Hubbard and Hansen 1976) and diet surveys for different species without regard to season or vegetation type (Hansen and Clark 1977). This method is probably the best method presently available to managers. Although subject to some of the same limitations as discussed for rumen

content analysis, collection of sample material is easier and the legal ramifications of obtaining samples, other than during hunting seasons would be avoided. Adequate sample series could be obtained and multiple collections from single animals would be possible in certain cases such as following radio-collared animals or tracking an individual after a recent snowfall (Severson and Medina 1984).

The fecal sampling procedure does not interfere with normal habits of the animal, places no restriction on animal movement, allows unlimited sampling and is the only feasible procedure to study secretive or endangered species (Crocker 1959, Anthony and Smith 1974). The results obtained using this technique are representative of the animal through its entire range. One to several days' diet is integrated into one sample and is not limited to a few hours of observation a day as in esophageal sampling (Scott and Dahl 1980).

Dietary Botanical Analysis Procedures

The primary methods of dietary botanical analysis have been reviewed by Theurer (1970), Ward (1970), Theurer et al. (1976), and Holechek et al. (1982). These methods have been grouped into four broad categories: visual appraisal, manual separation by weight or volume, microhistological and microscope point techniques. Visual analysis without the aid of the microscope has provided only qualitative estimates of botanical components of the diet (Theurer et al. 1976). Most browse in fistula forage samples could be identified;

however, herbaceous plants were frequently masticated beyond recognition (Cook et al. 1958). Low precision of manual separation into major plant groups or individual species was highly associated with personal error when more than one individual performed the procedure. Microscope point and microhistological techniques were found to be the most promising methods for estimation of botanical composition (Theurer et al. 1976).

Microscope Point Technique

The microscope point technique, developed by Heady and Torell 1959) and illustrated by Harker et al. (1964), is a modification of the point method (Levy and Madden 1933) for determining species composition. This method involves identification of the plant which appears under the crosshair of a binocular microscope at 16X magnification. Percent species composition was then estimated from point data by means of regression equations. Heady and Van Dyne (1965) found percent point and percent weight of certain annual grasses and forbs to differ from a 1:1 ratio. The ratio varies among species and during the growing season because of changing thickness, shattering and varying proportions of plant parts. Conversion factors have been developed by various investigators to correct these deviations. Galt (1972) related point to volume and applied a density constant to point estimates. Lesperance et al. (1970) developed correction factors relating surface area to weight.

Different observers were able to estimate consistently the amount of different plant species in known mixtures. This

consistency renders the technique feasible for quantitative estimation of botanical composition of the diet (Harker et al. 1964, Galt et al. 1968).

Microhistological Techniques

Microhistological identification of various plant species consumed by herbivores was described by Baumgartner and Martin (1939) and later refined by Dusi (1949). Sparks and Malechek (1968) verified the technique by accurately estimating percent composition (dry weight basis) of 15 mixtures of grasses and forbs. These mixtures were sampled by recording frequency of occurrence of each species in 100 microscope fields under 125X magnification. Frequency percentage was converted to density using the table developed by Fracker and Brischle (1944), and relative density was calculated. Dry weight percentages were predicted directly from relative density.

Gill et al. (1983) recognized four assumptions of the microhistological technique:

1) Fragments of every ingested plant species and plant part within species are recoverable and identifiable in fecal samples (Storr 1961).

2) Recovery or identification rates of plant fragments are consistently proportional to ingestion rates of plant species and/or plant parts, or digestion correction factors can be developed to account for differential digestion biases (Dearden et al. 1975, Fitzgerald and Waddington 1979).

3) The method is repeatable among technicians with similar training (Sparks and Malechek 1968).

4) A predictable relationship exists between frequency of occurrence of dietary items in the sample and weight or density of those items (Sparks and Malechek 1968, Havstad and Donart 1978).

Present information indicates that microhistological analysis provides an accurate estimate of grazing ruminant diets (Stewart 1967, Free et al. 1970, Free et al. 1971, Sanders et al. 1980, and Johnson and Pearson 1981). For "mixed feeders" (particularly wild herbivores), the accuracy of this technique is questionable (Zyznar and Urness 1969, Slater and Jones 1971, Todd and Hansen 1973, Anthony and Smith 1974, Westoby et al. 1976, Vavra et al. 1978, Pulliam and Nelson 1979, Smith and Shandruk 1979, Holechek et al. 1982, and Gill et al. 1983).

The reasons postulated to account for this inconsistency include: differential rates of digestion of plant species, plant parts and plants of varying phenological stage (Slater and Jones 1971, Dearden et al. 1975, Vavra and Holechek 1980, and Sidahmed et al. 1981), differential detection and recognition of plant species during microscopic examination (Westoby et al. 1976, Havstad and Donart 1978, Sanders et al. 1980, and Leslie et al. 1983), differential particle size reduction and recognition induced during sample preparation (Crocker 1959, Westoby et al. 1976, Holechek 1982) and analytical biases (Anthony and Smith 1974, Holechek and Vavra 1981, and Johnson 1982).

Sample Preparation Techniques

Slides of an identified plant can be prepared from leaves, stems, flowers, seeds, or the entire plant. Diagrams and photographs of cuticle patterns, in conjunction with these slides, form permanent references for the identification of cuticle fragments found in feces of herbivorous animals (Crocker 1959, Stewart 1965, Krueger 1972). Photomicrographs or drawings of the reference slides will reduce the microscope labor and accelerate the process of diet determination (Stewart 1965). Various methods of slide preparation have been developed, including tissue maceration, scraping and grinding.

Maceration

Crocker (1959) collected fresh leaves and macerated them in 50% nitric acid in a heated water bath. The tissue was then rinsed with water to remove the acid, and the cuticle was gently separated from the remainder of the leaf using mounted needles and a camel's hair brush. The cuticle was then cleared of any remaining cellular material with a fine jet of water and a brush. The slides were then subjected to a progressive (15% to 95%) alcohol series, stained with 1% acid fuschin and permanently mounted in Euparal. Diagrams were made using a projection method and a camera lucida attachment, and photographs were taken with a Leitz Panphot microscope and a 35-mm Leica camera.

Storr (1961) cut large leaves or trimmed small leaves and placed them in a 150-ml flask containing 5 ml each of 10% nitric and 10% chromic acid. The flask was fitted to a reflex condenser,

allowed to boil until the mesophyll disintegrated and the two integuments of each leaf drifted apart. After maceration, the contents of the flask were poured into a 250-ml beaker, which was topped with tap water, and a few drops of ammonia were added. The plant fragments were decanted into a centrifuge tube and dyed with an alcoholic solution of gentian violet. The dye was removed by washing with alcohol and the contents of the tube were poured into a petri dish.

Macerating techniques which subject plant tissue to high temperatures, concentrated acid, alkali or strong oxidizing agents (Dusi 1949, Crocker 1959, Storr 1961) are useful for plant species with epidermis which cannot be removed mechanically. This technique, however, may result in destruction of the epidermis (Stewart 1965) or alteration of cell volume (Letham 1958).

Scraping

Metcalfe (1960) placed a portion of leaf with the required epidermis face down on a slide. He added a bleaching agent and scraped the leaf with a sharp safety razor blade. The epidermal layer was washed with water, and a camel's hair brush was used to remove any undesired cells. Krueger (1972) soaked leaf, stem and root material in water until soft. A segment of plant material was placed on a slide and scraped on both sides with scalpel. Hoyer's solution was applied and a needle was used to separate plant fragments. The slides were heated in an oven at 40°C for 48 hr.

Grinding

Microscope slides of reference plants were prepared by Sparks and Malechek (1968) using oven-dried plant material which had been ground through a 1-mm screen to reduce all plant fragments to a uniform size. After grinding, material to be used for slide preparation was washed with water over a soil screen with 0.01-mm openings to eliminate any contaminating soil and small fragments. A small portion of sample was spread on the slide evenly and mounted using Hertwig's or Hoyer's solution. The slides were oven dried at 60°C.

Recognition Items

Plant cuticle is a continuous layer on the outer shoots of green plants and is formed by the polymerization of unsaturated fatty substances. When cell growth ceases, the cuticle hardens to a solid film moulded to the contours of the underlying epidermal cells. When the cuticle is separated from the leaf, it bears an imprint of and sometimes contains parts of the cells of the epidermis (Hercus 1960).

The cuticle is impermeable to water and resistant to most chemicals and the action of microbial organisms. During digestion the cuticle passes through the animal unchanged. The cuticle fragments in the feces display an outline of the epidermal cell pattern of the plants from which they are derived, and in this way it is possible to obtain information as to which plants the animals consume (Hercus 1960).

Epidermis

The arrangement of the epidermal cells is a characteristic of plant families (Hercus 1960, Stewart 1965) used to classify genera of a family (Stewart 1965, Davies 1959) and species or subspecies of the genera (Hercus 1960, Storr 1961, Kok and Van Der Schijff 1973). While conditions of growth may influence cell dimensions, the pattern of arrangement is characteristic of a given plant (Hercus 1960).

The epidermal cells of monocotyledonous plants are arranged in rows parallel to the venation and axis of the leaf. The lamina of a grass leaf in surface view is divided horizontally into intercostal zones (between the veins) and costal zones (over the veins). The epidermis of most grasses is composed of long and short cells. The long cells are elongated horizontally and are relatively narrow vertically. They vary in length and their walls vary in thickness as well as in extent to which they are sinuous or pitted.

The short cells occur in horizontal rows, and occur solitary or in pairs. They are generally classified as silica cells when each cell is nearly completely filled with a single silica body or cork cells when their walls give the reaction of cork (Metcalfe 1960).

The silica bodies in the silica cells are of great significance for diagnostic and taxonomic purposes. All silica bodies over the vein are usually of one type. Other silica bocies, frequently smaller and differently shaped than those over the veins, may occur in the intercostal zones. They are more widely spaced and are

frequently accompanied by a short cell without silica called a cork cell. Cork cells have suberized walls and often contain organic material (Esau 1953). The silica cell and the cork cell combined are referred to as a silica-suberose couple. The silica bodies assume different shapes. They may be dumbbell-shaped, cross-shaped, crescent-shaped, nodular-shaped or saddle-shaped (Kok and Van Der Schijff 1973). The unsuberized epidermal cells may be described according to their shape, size, wall characteristics and inclusions.

Dicotyledons are characterized by the presence of hexagonal cells with some degree of elongation, while those of monocotolydons are elongate rectangular. The cell size within a leaf may vary in that the diameter of the largest cell commonly exceeds twice that of the smallest cell. However, the difference in mean cell size between two related species may be dramatic that it may be a diagnostic aid (Storr 1961). Metcalfe and Chalke (1950) found that the size, shape and wall characteristics of epidermal cells varies from year to year and location to location, which minimizes their diagnostic value.

Stomata

Stomata are apertures in the epidermis, each of which is surrounded by two guard cells. In many plants, two or more cells adjacent to the guard cells are morphologically distinct from other epidermal cells. Such cells are called subsidiary or accessory cells (Esau 1953).

In monocotyledonous plants stomata are arranged in rows, and are restricted to the intercostal zone in grasses (Esau 1953).

Their frequency, shape, and number varies with area (Liversidge 1970). Metcalfe (1960) recognized five types based on shape of the subsidiary cells. Kok and Van Der Schijff (1973) considered this criterion to be of minor taxonomic value for grasses.

In most dicotyledonous plants, stomata are scattered over the leaf surface in depressions below the level of the epidermal cells, or are restricted to grooves or cavities in the leaf surface (Cutter 1969). The stomata of forbs generally have two moon-shaped guard cells, while those of shrub or woody species possess small, kidney-shaped guard cells (Scott and Dahl 1980).

Fahn (1974) recognized four primary types of stomata on the basis of the arrangement of the subsidiary cells:

1) Anomocytic type: in which the guard cells are surrounded by an indefinite number of cells which do not differ in size or shape from other epidermal cells.

2) Anisocytic type: in which the guard cells are surrounded by three unequally sized subsidiary cells.

3) Paracytic type: in which one or more subsidiary cells are present with their long axis parallel to the guard cells.

4) Diacytic type: or crossed celled in which two subsidiary cells surround the stomata with their common wall at right angles to the guard cells.

Crystals

Crystals of various chemical nature, size and shape occur in many dicotyledons and certain monoctolydenous plants. The form and distribution of crystals is often of diagnostic value (Metcalfe 1971). Cutter (1969) recognized five types of crystals:

1) Single or twin prisms, either rectangular or pyramid shaped, and rhomboid crystals may occur in veins or parenchyma tissue.

2) Druses are spherical aggregates of crystals composed of many prisms or pyramids, with projecting points covering the surface. They are abundant in both veins and parenchyma tissue.

3) Raphides are long and needle-shaped, pointed at both ends, and are usually aggregated in bundles. They are abundant in parenchyma cells of soft tissues and tissues of aquatic plants.

4) Sandy crystals are very small crystals which are frequently massed together.

5) Cystoliths are considered as crystalline bodies, which consist of cell wall substances.

Epidermal Appendages

Monocotyledons. Epidermal appendages are outgrowths of the epidermis and are commonly present on monocotyledonous leaves. Four types of appendages exist, including macrohairs, microhairs, prickle-hairs and papillae.

Macrohairs are long, unicellular trichomes which are usually visible to the naked eye or with a simple hand lens. They vary in length, cell wall thickness, and whether their bases are superficial or penetrate between adjacent epidermal cells (Metcalfe 1960). When the bases of the hairs are sunken they are sometimes surrounded by epidermal cells which may or may not be raised above the surface of the leaf in a collar around the base of the hair. Macrohairs of this type are often referred to as cushion hairs. Macrohairs generally occur over the veins or at the leaf margins. Their number varies from plant to plant, and even within the same leaf the basal parts are usually more hairy than the middle or the distal part. Thus, presence or absence of macrohairs, as well as form and type of attachment of hairs are diagnostically important (Mecalfe 1960).

Microhairs are much smaller than macrohairs. They are generally two celled, though one-celled trichomes sometimes occur. Four types of microhairs, based on shape of the basal cell and length of the distal cell, are recognized by Kok and Van Der Schijff (1973).

Pricklehairs are short unicellular trichomes with thick, lignified walls, pointed barbs and a round or an oval base (Metcalfe 1960). They occur between silica bodies between the veins and give many grasses a rough texture. Small prickles, referred to as hooks, usually occur in intercostal veins (Mecalfe 1960). Three types of pricklehairs, based on shape of the leaf, were recognized by Kok and Van Der Schijff (1973).

Papillae are variously shaped protrusions on the outer surface of long cells in the intercostal zone (Metcalfe 1960). They are divided by Kok and Van Der Schijff (1973) into two groups: large single papilla or many small papillae on each cell. They are a conspicuous and consistent feature of the epidermis of the species in which they occur (Stewart 1965).

Dicotyledons. Epidermal appendages represent the most important characteristic for identification of genera and species of dicotyledonous plants (Metcalfe and Chalke 1950). Epidermal appendages have been classified by Fahn (1974) into two main groups: glandular and non-glandular trichomes. The non-glandular trichomes include simple unicellular or multicellular non-flattened hairs, squamiform hairs which are conspicuously flattened and multicellular, branched multicellular hairs, and shaggy hairs which consist of two or more contiguous rows of cells. The glandular trichomes include trichome-hydathodes, salt-secreting trichomes, nectar-secreting trichomes, mucilage-secreting trichomes, terpene-secreting trichomes, collectors and stinging hairs.

Mule Deer Food Habits

There is extensive literature on food habits of mule deer. Severson and Medina (1984) reported that 99 food habit studies have been conducted throughout the animal's range. At present there is no published food habit data for the mule deer population of south-central New Mexico.

In the Southwest, 14 food habit studies were conducted on mule deer. These studies revealed that although mule deer consumed 327 plant species, relatively few species comprise a large portion of their diet (Severson and Medina 1984). Hunt (1978) noted that mule deer consumed 113 of the 194 plant species found at Fort Bayard, New Mexico, but only 10 species were present in quantities equal to or greater than 1% of the deer's diet. He also observed that deer used 81, 63, 16, and 32 species during summer, fall, winter and spring respectively; but only 19, 16, 4, and 7 species comprised more than 1% of the diet each.

In the mountainous areas, mountain mahogany, cliffrose, oaks and Wright's eriogonum are the most abundant species in diets of mule deer. Incidence of heavy use of oak, junipers, mesquite, excepting fruits, and ponderosa pine has been attributed to necessity rather than preference (Anderson et al. 1965, Severson and Medina 1984).

Mast and cactus fruits constitute an important portion of mule deer diets, and many of the least preferred browse plants contribute significantly through their fruit crop (Short 1977, Hunt 1978).

Forbs are important food items of mule deer diets and they are used heavily during spring and summer. The studies conducted on pinyon-juniper winter ranges in the Southwest revealed a greater proportion of forbs in fall and winter diets than that found in deer food studies from other areas (Severson and Medina 1984).

Cool-season grasses, the first to initiate green growth, are important in spring and early summer for a short period. Perennial cool-season species, such as bluegrass, orchardgrass and wheatgrass are important in high elevation areas, and introduced seeded species appear to be more palatable than native species (Hungerford 1970).

Although considered as miscellaneous food items because of their low availability, mushrooms (Hungerford 1970) and mistletoe (Hunt 1978) were noted as being used wherever available in most food habit investigations.

DESCRIPTION OF THE AREA

Fort Stanton was established as a military fort in 1855. In 1896 the fort was abandoned and the area was used as a site for a sanatorium for treatment of Merchant Marines suffering from tuberculosis. The fort was operated as a sanatorium from 1899 to 1952. With the advent of new methods for treatment of tuberculosis, the Public Health Service deemed the facility unnecessary, and the hospital and 534 surrounding hectares were made available for the New Mexico State Department of Public Welfare. The remaining area was placed under the jurisdiction of the General Services Administration, with the Bureau of Land Management (BLM) having custodial care.

In 1963, the BLM signed an agreement with the New Mexico Experiment Station for use of the area as a livestock, wildlife, and range research station. This agreement was a yearly agreement until 1970 when a 20-year lease was signed (Bailey et al. 1982).

Location

The Fort Stanton Experimental Ranch is located in southern Lincoln County, New Mexico, in the foothills between Capitan and the Sierra Blanca Mountains. It encompasses an area of 10522 hectares at latitude 33°30' north and longitude 105°31' west (Wood et al. 1978). It has an elevation which ranges between 1900 and 2300 m (Thetford et al. 1971). The topography is characterized by deep canyons and relatively level mesas between the canyons

(Pieper et al. 1971). The Rio Bonito, an intermittent stream, provides the principal drainage and bisects the area from west to east (Wood et al. 1978).

Geology and Soil

The area is underlaid by the San Andres formation, which is composed of limestone and dolomites of Permian age (Allen and Jones 1952, U.S. Department of Agriculture 1965). The San Andres formation is exposed on the east side of the ranch. A central strip is composed of undifferentiated rock of dolomite, sandstone, siltstone and shale of Guadalupe age. On the northwest portion the San Andres formation is overlaid by undifferentiated Trissaic rocks of sandstone and shale (U.S. Department of Agriculture 1965).

Soils on the Fort Stanton Ranch are of two soil orders: Mollisol and Inceptisol. Three great groups within the Mollisol order are represented, all of which are in the ustoll suborder. These are Agriustolls, Calciustolls and Hapiustolls. There are fifteen different subgroups within these great groups. The only soil surveyed in the inceptisol order was an Aridic Ustchrept.

Soils of the mesa tops and bottomlands are Aridic Haplustolls and Typic Torrifulvents, respectively, and they are generally deep, well-drained calcareous soils with textures ranging from loams to clay loams (U.S. Department of Agriculture 1965, Lymbery and Pieper 1978). The pinyon-dominated slope soils are Lithic Calciustolls, Lithic Haplustolls or Petrocalcic Calciustolls. The depth of these soils ranges from 16 to more than 62 cm and their textures vary from

sandy loams to heavy clay loams. Riverbottom soils are Torrifluvents and alluvial, and they are composed of a conglomerate of geological materials (Smith 1980).

Climate

The area is characterized by cool winters and warm summers. The mean annual and maximum temperatures are 11.1 and 18.6°C, respectively. The coldest month is January with a mean minimum temperature of -6.7°C and the warmest month is July with a mean maximum of 28.9°C (Pieper et al. 1971). The average frost-free period is 161 days, with October 10 as the average date of first frost and May 2 as the average date of the last frost (Schickedanz 1970).

The mean annual precipitation is 38.39 cm. The growing season, which extends from June through September, receives an average of 24.4 cm, which constitutes 62.8% of the total rainfall (Pieper et al. 1971). Precipitation data for the study period 1981-1983 are shown in Table 1.

Vegetation

The Fort Stantion Experimental Ranch includes three major vegetation types: riparian, blue grama grassland and pinyon-juniper woodland (Lebgue 1982).

The riparian vegetation occurs near the Rio Bonito and Salado creeks. Woody plants of the riparian habitat include coyote willow (*Salix exigua* Nutt.), peachleaf willow (*S. wrightii* Anders), bigleaf maple (*Acer negundo* var. *interius* (Britt.), narrow-leaf cottonwood (*Populus angustifolia* James), lance-leaf cottonwood (*Populus*

Table 1. Monthly precipitation (cm) for the Fort Stanton Experimental Ranch.

Month	1981	1982	1983
January	0.53	2.40	2.46
February	0.57	0.64	2.31
March	0.15	0.61	2.72
April	0.96	0.01	3.56
May	6.28	0.64	2.57
June	3.74	0.09	1.42
July	8.04	7.13	3.79
August	12.95	9.24	1.41
September	7.30	8.06	2.78
October	2.08	4.97	2.45
November	0.91	2.29	1.89
December	---	2.28	0.55
Total	43.51	38.36	27.91

acuminata Rybd.), walnut (Juglans major (Torr.) Heller), gambel oak (Quercus gambelii Nutt.) and tamarisk (Tamarix pentandra Pall.). The herbaceous cover occupying the wetland areas consists of Kentucky bluegrass (Poa pratensis L.), red top (Agrostis stolonifera L.), bullrush (Scirpus validus Vahl., S. americanus Pers.), cat-tail (Typha angustifolia L.), rush (Juncus interior Wieg), horsetail (Equisetum laevigatum A. Braun), summer-cypress (Kochia scoparia (L.) Schard.) and wild-rye (Distichlis spicata var. stricta (Torr.) Beetle).

The blue grama grassland vegetation type occurs on a major portion of the Salado pasture and on scattered locations on mesa tops and bottomlands. This vegetation type is dominated by blue grama (Bouteloua gracilis (H.B.K.) Lag.) and is interspersed by sideoats grama (Bouteloua curtipendula (Mich) Torr.), hairy grama (Bouteloua hirsuta Lag.), sand dropseed (Sporobolus cryptandrus (Torr.) Gray), wolftail (Lycurus phleoides H.B.K.), ring muhly (Muhlenbergia torreyi (Kunth.) Hitch.) and galleta (Hilaria jamesii (Torr.) Benth). Considerable amounts of walkingstick cholla (Opuntia imbricata (Haw.) DC.) and broom snakeweed (Gutierrezia sarothrae (Pursh) Britt. and Rusby) are scattered within the herbaceous cover. The most important forbs in this vegetation type are carruth sagewort (Artemisia caruthii Wood), scarlet globemallow (Sphaeralcea coccinea (Pursh) Rydb.) and vervain (Verbena bipinnatifida Nutt.) (Pieper et al. 1973, Rippel 1978).

The pinyon-juniper woodland vegetation type dominates the slopes and rocky ridges that characterize most of the ranch. One-seed juniper (Juniperus monosperma (Englem.) Sarg.) and pinyon pine (Pinus edulis Engelm.) are the most common species. Alligator juniper (J. deppeana Steud) is less frequent. Common shrubs are wavy-leaf oak (Quercus undulata Torr.) and skunkbush (Rhus trilobata Nutt.). Fourwing saltbush (Atriplex canescens (Pursh) Nutt.), winterfat (Ceratoides lanata (Pursh) J. T. Howell), mountain mahogany (Cercocarpus breviflorus Gray) and fendlerbush (Fendlera rupicola Gray) are less frequent. The most common grasses include blue grama, sideoats grama and wolftail. The prevalent forbs include wild buckwheat (Eriogonum spp.), bladderpod (Lesquerella fendleri Gray), Louisiana sagewort (Artemisia ludoviciana Nutt.), common sunflower (Helianthus annuus L.), blueweed (Helianthus ciliaris L.), green thread (Thlesperma filifolium (Hook) Gray) and western yarrow (Achillea millefolium var. lanulosa (Nutt.) Piper) (Pieper et al. 1973, Rippel 1978).

Wildlife

The rich and varied habitat of Fort Stanton supports a wide diversity of wildlife species. A total of 74 species of birds, representing 12 orders and 31 families, and 35 species of mammals, representing 6 orders and 16 families, are present.

The riparian habitat supports eight bird species including the killdeer (Charadrius vociferus), the mourning dove (Zenaidura macroura) and mallard (Anas platyrynchos). None of the mammals uses

the riparian habitat to the exclusion of any of the other habitats.

The grassland vegetation type supports 12 species of birds, including scaled quail (Callipepla squamata), Montezuma quail (Cyrtonyx montezuma), roadrunner (Geococcyx californianus) and western meadowlark (Sturnella neglecta).

Nine species of mammals are associated with the grassland vegetation type and these include the pronghorn antelope (Antilocarpa americana), spotted ground squirrel (Spermophilus spilosoma), silky pocket mouse (Perognathus flavus) and hispid pocket mouse (Perognanthus hispidus).

The remainder of the mammals and about 55 species of birds use the pinyon-juniper woodland. Junipers are found to be important for feeding, courtship, nesting and thermal cover for birds (Thompson and Hier 1981).

Mule Deer

The Fort Stanton mule deer herd occupies the pinyon-juniper vegetation type that, prior to the development of livestock and big game water, served primarily as a winter range. Average summer and fall densities fluctuated between three and seven deer per square kilometer.

The herd composition varied among years. The fall buck:doe ratio ranged from 26 to 49 bucks per 100 does, with an average of 40 bucks to 100 does. The legal harvest for 5 years ranged from 43 to 64 and averaged 53 bucks per year (Wood et al. 1978).

METHODS AND PROCEDURES

Transect Establishment

Twenty-six transects were established in 1964 and 1965 on the Fort Stanton Experimental Ranch by Wood et al. (1978). These transects were randomly located in areas representing deer habitat by gridding aerial photographs, drawing random numbers to select locations, and plotting these locations on an aerial photograph. The areas were later identified in the field. Twenty-two additional transects were established in 1967 in deer habitat locations that were sparsely sampled by the first set of transects. The location and direction of each of these transects were randomly determined (Fig. 1). Each transect consisted of ten 40.47-m^2 plots, with plots spaced at 30.5-m intervals along the baseline. Plot centers were marked with a stake painted with orange tree-and-log marking paint to maintain visibility for plot relocation. Smith (1968), in a comparison of various-sized circular plots, found this plot size to be most efficient for collecting deer pellet groups.

Vegetation Sampling

Vegetation was sampled in August and September of 1983 to determine cover of woody and herbaceous species. Browse transects were established at the first and fifth stakes of each of the 48 transects. They were 30.5-m line transects (Canfield 1941). The beginning point for each browse transect was 3.6 m from the pellet group transect stake. The directions for browse transects were

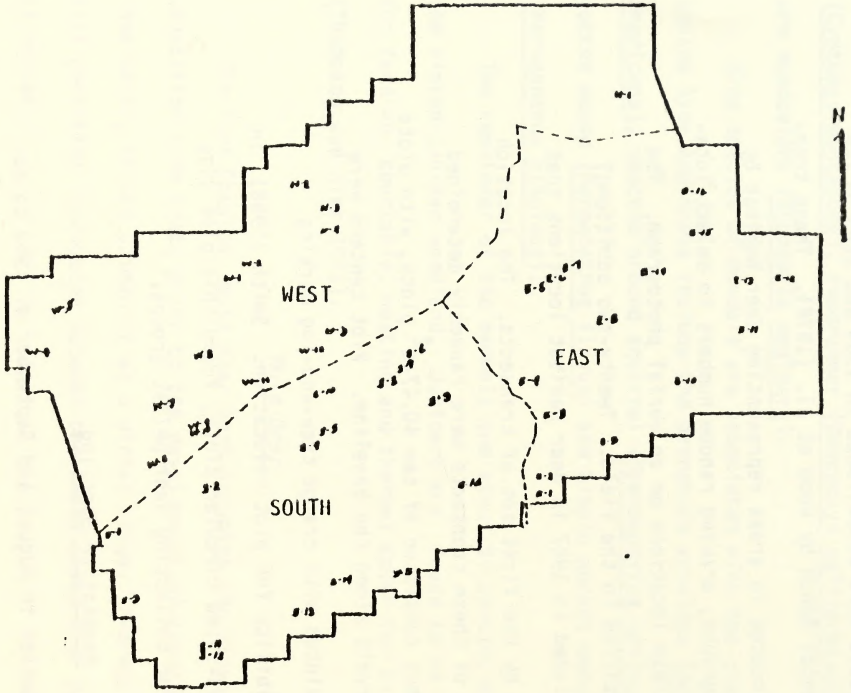

Figure 1. Map of Fort Stanton Experimental Ranch showing locations of pellet-group transects in the three main sections.

randomly selected except for those used in pellet transects. Included in the intercept measurements were leaves and stems of browse up to 1.8 m above ground. The line-intercept method has long been recognized as an accurate and fairly precise method, but is tedious and time-consuming (Pieper 1978).

Herbaceous species were sampled using the step-point method. The method consisted of recording whatever appeared under the tip of the boot as the sampler paced across an area (Evans and Love 1957). The step-point transects were established at the first and fifth stakes of each of the 48 transects. Each transect consisted of 100 steps. The beginning point for each step-point transect was 3.6 m from the pellet-group transect stake. Directions for the step-point transects were randomly selected except that directions used for browse transects and pellet-group transects were not utilized. Cover classes recorded were individual species, litter, and bare ground. If the aerial portion of a plant was not directly beneath the needle at the tip of the boot, then the species nearest to the point was recorded for composition calculations.

Point sampling as described by Levy and Madden (1933) represented reduction in quadrat size to a dimensionless point. Many changes have been introduced for the apparatus used for point sampling and the method of placement of the points. Heady et al. (1959) used line-point transects. Point sampling allowed quantitative determination of ground cover, species composition, basal area and leaf area. This technique was objective, unbiased, and can be randomized and replicated to provide the desired precision.

Some studies observed slightly higher cover values with the point method than with the line-intercept (Whitman and Siggeirsson 1954, Johnston 1957). This overestimation was attributed to the dimension of the pins (Johnston 1957).

Pellet Group Sampling

Deer pellets were collected within the circular plots. The perimeter of each plot was marked with a 3.59-m long chain. Plots were circled clockwise and then counter-clockwise to insure detection of all pellet groups within the plot. A few pellets were collected from each pellet group and the remaining pellets were painted with Nelson-spot tree-marking paint to guard against future re-collections. Groups on the plot boundary were collected only when at least half of their pellets occurred inside the plot. The minimum number of pellets considered to be a pellet group was ten. A composite sample of deer pellets was made for each transect. Pellets collected were placed in paper bags and the date and transect location were recorded. They were later oven-dried at 50°C and ground in a Wiley mill using a delivery tube with a 20-mesh (1 mm) screen.

This study was conducted from June 1981 through September 1983. Seven pellet-group collections were made during this period--on June 1981, September 1981, July 1982, September 1982, March 1983, June 1983 and September 1983, representing spring, summer and fall. Winter collections for all of the three years were cancelled due to heavy snowfall.

Reference Slides

Reference slides were prepared from plants occurring around the pellet group transects. Correct taxonomic identificaiton was made possible by comparison of collected plants with herbarium specimens preserved at the ranch headquarters. Whole herbaceous plants, twigs of shrubs, leaves, stems, flowers, and fruits, when possible, were collected and oven-dried at 50°C. A sample was obtained from each plant or plant part and ground in a Wiley mill using a delivery tube with a 20-mesh (1 mm) screen. After grinding each sample, the mill was thoroughly cleaned with a brush and compressed air.

Slide Preparation

Microscope slides were prepared using a method similar to that described by Sparks and Malechek (1968) and Hansen et al. (1971). The materials needed for slide preparation were: standard 75x25-mm glass microscope slides, 22x40-mm glass cover slips, slide labels, dropping bottles, teasing needles, spatula, paper towels, 200-mesh screen, drying oven, household bleach and Hoyer's solution as a mounting medium.

Hoyer's solution consisted of 200 g of chloral hydrate crystals, 50 ml distilled water, 50 ml glycerin and 50 g photo-purified gum arabic. Chloral hydrate crystals were added to water and glycerin. The mixture was warmed until the crystals dissolved. Gum arabic was added to the solution which was stored in a dark place until the gum arabic dissolved completely and the solution cleared.

A subsample of 5-10 g of ground vegetation material or fecal sample was soaked with household bleach for 24 hr in a 50-ml glass beaker to remove plant pigments. The subsample was placed in a 200-mesh (0.047 mm) soil screen and washed with hot water to rinse off bleach and solubles and to remove dirt and small non-diagnostic plant particles.

A small amount of the washed material was removed from the screen with a spatula and placed on a 75x25x1-mm metal template with a 5-mm opening. The purpose of the metal template was to insure equal amounts of material on each slide. The opening of the template was filled with this material which was then transferred to a glass slide.

Hoyer's mounting medium was added to the material on the slide to cover an area about two-thirds as large as the cover slip. The material was mixed thoroughly with Hoyer's solution using a teasing needle, and then was evenly spread over an area as large as the cover slip. The cover slip was placed over the slide and a thin ring of Hoyer's solution was applied around the edge of the cover slip to form a seal as the medium dried. Slides were placed on level racks in an oven set at 50°C until the Hoyer's solution hardened, and were then stored in a dry place. Hoyer's solution formed a relatively permanent mounting medium when it solidified, but it was soluble in water, permitting easy cleaning for slide reuse.

Diet Quantification

Diet quantification followed the procedure of Hansen et al. (1971). Pellets collected from each plot were composited by transect. Five slides were made of each composite sample. Twenty fields of view were systematically located on each slide at 100-400X magnification. Presence of plant species in a field was determined by the identification of cellular material, which guarded against over-estimation of species with easily identifiable trichomes. Percentage dry weight by species was calculated following the frequency addition procedure outlined by Holechek and Gross (1982).

Accuracy of the Estimates

Accuracy of the microhistological estimates obtained in this study were determined by analysis of six artificially made mixtures (Appendix Table 12). Mixtures included from 5 to 13 of the most common species in the study area and contained variable amounts of grasses, forbs and shrubs. All plants used in the mixtures were actively growing when collected. The plant material was air dried and ground through a 1-mm screen to reduce all plant fragments to a uniform size. The mixtures were compounded from various combinations of species so that compositions of no two mixtures were alike. Five slides were prepared from each mixture and composition was determined following the same procedure that was used for diet estimation in this study. The species and dry weight composition of mixtures were unknown to the author until after sample estimates were made.

Diagnostic Characters

Microhistological technique was based on identification of individual plants from their epidermal characteristics. Epidermal cells varied in size, shape and arrangement, but they were always closely attached to each other to form a compact layer devoid of intercellular spaces. Guard cells together with the openings between them constituted the stomata which were a characteristic feature of photosynthesizing tissue. On the outer wall of epidermis a cuticular layer existed which varied in thickness in different plants. The cuticle was impermeable to water and resistant to most chemicals and microbial action. It passed unchanged through the animal's digestive tract. The cuticle fragments in the feces displayed an outline of the epidermal cell patterns of the plants from which they were derived, and in this way it was possible to obtain information as to which plants the animals consumed (Hercus 1960).

Terms used in description of plant diagnostic characters followed Esau (1953), Metcalfe (1960), Cutter (1969) and Fahn (1974). The results of this study were obtained using a compound binocular microscope under 100X magnification to view epidermal cells and appendages. To reveal stomatal types and guard cell arrangements, 400X magnification was used.

Browse

Trees and shrubs usually possessed small stomata. The guard cells which surrounded the stomatal pores were generally kidney-shaped with small pores, and epidermal cells were smaller than

those of forbs. Trichomes when present were generally unicellular. It was noticed that plant pigment was not completely removed during the process of digestion and slide preparation which obscured some of the diagnostic characters.

The epidermis of wavyleaf oak was characterized by partly lignified epidermal cell walls and ranunculaceous stomata. Trichomes were present with long pointed peltate multicellular hairs. The cuticle extended on the guard cells and covered part of the stomatal pore. Small clustered crystals were present on the epidermis. Plant pigment on wavyleaf oak was not completely removed during the process of digestion and slide preparation. This might be attributed to tannin which Meyer and Meola (1978) reported to be contained within parenchyma cells.

Skunkbush possessed a ranunculaceous stomata with edges of the guard cells extending outwardly and partially covering the pore. Numerous trichomes were present. They were mostly intercellular hairs with a few multicelled glandular trichomes.

The reference slides made of important plants from the Fort Stanton Experimental Ranch included three species of gymnospermae. These were pinyon pine, one-seed juniper and alligator juniper. The epidermis of the three gymnosperms consisted of thick-walled cells and was heavily cuticularized. The stomata occurred in longitudinal rows. They were deeply sunken and were overlapped by the subsidiary cells. Esau (1964) noticed that the front cavity of the stomata was typically filled with whitish occluding material that facilitated their recognition. Though pinyon and juniper can be easily

distinguished based on epidermal cell wall characteristics, the author could not find a criterion to facilitate distinction between the two Juniperus spp.

Forbs

Trichomes constituted an important diagnostic character of forbs. There were two types of trichomes--unicellular and multicellular. Unicellular trichomes could be straight, curved, smooth, pubescent, branched, unbranched, attached at the ends, or attached at the centers. Multicellular trichomes could be dentroid, peltate, stellate or arranged in a single row. The epidermal cells and the stomata of forbs were generally larger than those of shrubs. The two guard cells which surrounded the stomatal pores were usually half-moon shaped with a wide pore.

The epidermis of snakeweed was characterized by polygonal cells with a wrinkled appearance. Epidermal appendages consisted of multicellular short pointed trichomes. The stomata was a paracytic type on which guard cells were accompanied by subsidiary cells.

Buckwheat was characterized by unicellular string-like trichomes and large crystals. Fahn (1974) reported the presence of tannin-containing cells within the epidermal leaves. Carruth sagewort possessed multicellular string-like trichomes which were narrower than those of buckwheat and its epidermal cells were characterized by elongated smooth cell walls. Vervain was characterized by unicellular rigid unbranched elongated trichomes with pointed tips. The stomata were ranunculaceous and slightly raised over the surface of the epidermal cells. Scarlet globemallow was quite

distinctive with its multicellular stellate trichomes with arms wider at base and pointed tips. The stomata were of anomocytic type. Epidermal cells of scarlet globemallow contained specialized cells with mucilaginous contents (Fahn 1974).

There was a tendency for the epidermal appendages of certain plant species to shatter easily during digestion and slide preparation procedures. To attain an accurate estimate of these species in a diet, only trichomes attached to plant fragments were counted.

Statistical Procedures

Wood et al. (1978) stratified deer habitat of the Fort Stanton Experimental Ranch into three topographic areas: the west, the south, and the east pastures. The west pasture encompassed 2072 ha of deer habitat in the northern and western portions of the ranch. The principal topographic features were rolling hills and wide grassy canyons. The south pasture encompassed 2072 ha of deer habitat in the southern portion of the ranch. The principal topographic features were two large plateaus bordered by deep canyons. The east pasture encompassed 3108 ha of deer habitat in the eastern portion of the ranch. The principal topographic features were a complex of steep narrow brush canyons and ridges.

A restricted random design was used to lay out 48 transects; 16 on each of the west, south and east pastures. Data from line-intercept transects were expressed as percentage of ground cover and botanical composition. A general linear model procedure used the statistical method of variance analysis to detect differences in cover and botanical composition of woody species between the three

pastures. A completely random design was used to analyze the data with 16 transects on each pasture as replicates. Means were separated by use of the least significant difference (LSD). A level of significance of 0.05 was used unless stated otherwise.

The one-way analysis of variance with a completely random design was used to compare cover classes among pastures and means which were separated using the least significant difference (LSD).

The statistical design adopted to analyze mule deer diet was a 3x3 factorial randomized block design. The two factors involved were years and pastures. Nine blocks existed, each representing a pasture in a specific year. Deer pellets were collected at the end of spring and summer of each year in each pasture. The objective of the analysis was to detect differences among seasons, years, locations, and their interactions.

RESULTS AND DISCUSSION

Habitat Characteristics

The foundation of any habitat management plan is the ability to assess habitat quality accurately (Van Horne 1983). However, the methodology to determine properly the relationship between the animal and its habitat and the predictability of the effects of habitat modifications on animal population are lacking (Severson and Medina 1984). Vegetation sampling is essential for all habitat evaluation studies. It constitutes a rapid means of assessment of habitat quality, habitat quantity and habitat use by providing essential information on available food and cover.

Browse Cover

Trees and shrubs of the Fort Stanton Experimental Ranch were sampled by Wood et al. (1978) to determine browse cover, composition and distribution. They divided the ranch into two broad areas: the stony hills of the northeast and the mesas and canyons of the southwest. Each area was characterized by a different topography and vegetation. Although no differences were found in percentage of total browse cover between the two areas, species composition was found to differ significantly.

Trees and shrubs were sampled in August and September of 1983 to determine available food and cover for mule deer. Fifteen browse species were sampled. Eight of these species contributed 98.78% total woody plant composition (Table 2). Their percent cover ranged between 10.52 and 0.06 for wavyleaf oak and fendlerbush respectively,

Table 2. Percentage cover and botanical composition of woody plant species on the Fort Stanton Experimental Ranch.

	PASTURE							
	West		East		South		Mean	
Species	Cover	Composition	Cover	Composition	Cover	Composition	Cover	Composition
Quercus undulata	6.52	30.34	11.52	37.78	13.51	55.32	10.52	41.30
Juniperus monosperma	5.29	24.62	9.78	32.07	5.17	21.17	6.75	26.50
Pinus edulis	5.41	25.17	5.95	19.51	3.85	15.77	5.07	19.91
Juniperus deppeana	2.42	11.26	1.17	3.84	0.26	1.07	1.28	5.02
Rhus trilobata	0.88	4.10	0.88	2.89	0.97	3.97	0.91	3.57
Berberis haematocarpa	0.24	1.12	0.66	2.16	0.23	0.94	0.38	1.49
Opuntia imbricata	0.16	0.74	0.17	0.56	0.25	1.02	0.19	0.75
Baccharis pteronioides	0.28	1.30	0	0	0.03	0.12	0.10	0.39
Prosopis glandulosa	0.28	1.30	0	0	0	0	0.09	0.35
Fendlera rupicola	0.01	0.05	0.14	0.46	0.04	0.17	0.06	0.24
Lycium pallidum	0	0	0.14	0.46	0	0	0.05	0.20
Fallugia paradoxa	0	0	0	0	0.08	0.33	0.03	0.12
Atriplex canescens	0	0	0.06	0.20	0	0	0.02	0.08
Cercocarpus breviflorus	0	0	0	0	0.03	0.12	0.01	0.04
Pinus ponderosa	0	0	0.02	0.06	0	0	0.01	0.04
TOTAL	21.49	100.00	30.49	99.99	24.42	100.00	25.47	100.00

and they were represented in all three pastures. Analysis of variance indicated no significant differences between mean percent cover for each species among pastures (Table 3).

Wavyleaf oak was the most abundant browse species in all of the three pastures. It constituted 30.34, 37.78 and 55.32% of the botanical composition of woody plants of the west, east, and south pastures, respectively (Table 2). The mean percent cover of wavyleaf oak was 10.52 averaged over all pastures. The oak occurred in dense stands and dominated shrubby vegetation on steep rocky slopes.

Wood et al. (1978) recognized differences in woody plants botanical composition between the northeast and southwest areas. Wavyleaf oak dominated the southwest area with a botanical composition of 52.93%, while one-seed juniper was most abundant on the northeast area and represented 44.03% of woody plant species composition, succeeded by wavyleaf oak which constituted 23.57%.

One-seed juniper represented 26.5% botanical composition of the three pastures with highest percentages in the east pasture (Table 2). It occupied slopes and rocky ridges. The mean percent cover of one-seed juniper was 6.75.

Pinyon constituted 25.17, 19.51 and 15.77% of botanical composition of woody plants of the west, east and south pastures, respectively (Table 2). It occurred on slopes and rocky ridges that characterized most of the ranch. The mean percent cover of pinyon was 5.07.

Table 3. Mean cover estimates for the most important browse species at all locations on the Fort Stanton Experimental Ranch.

	Percent Cover	Root MSE[1]	PR>F[2]
Quercus undulata	10.52	10.79	0.18
Juniperus monosperma	6.75	6.21	0.08
Pinus edulis	5.07	5.58	0.55
Juniperus deppeana	1.28	3.14	0.16
Rhus trilobata	0.91	1.10	0.96
Berberis haematocarpa	0.38	1.10	0.45
Opuntia imbricata	0.19	0.54	0.88
Fendlera rapicola	0.06	0.06	0.20

[1]Mean square error

[2]Comparisons among three pastures on Fort Stanton (west, south and east)

Alligator juniper occurred in low densities in the pinyon-juniper woodland habitat which dominated the slopes and rocky ridges. It constituted a major component of the woody plant community only in the west pasture (Table 2). The mean percent cover of alligator juniper was 1.28.

Percent cover of skunkbush was fairly uniform throughout the Fort Stanton Experimental Ranch. It constituted 3.57% composition in the three pastures (Table 2). Skunkbush represented less than 1% of woody plant cover of the ranch.

Red holly grape (Berberis haematocarpa) was found mainly along lower slopes. It represented less than 2% of the botanical composition of the pastures (Table 2). The mean percent cover of red holly grape was 0.38.

Walking-stick cholla occurred within the cholla-blue grama community (Lebeque 1982). This community was characterized by walking-stick cholla, blue grama, vervain and occasional plants of one-seed juniper. Walkingstick cholla contributed 0.74, 0.56 and 1.02% to the botanical composition of the west, east and south pastures, respectively. The mean percent cover of walking-stick cholla was 0.19.

Fendlerbush constituted less than 0.5% botanical composition of the three pastures, but was highest in the east pasture. Its mean percent cover was 0.06. The extremely hedged appearance of the fendlerbush was an indication of heavy utilization by mule deer.

Yerba-de-pasmo (Baccharis pteronoides) represented 1.30 and 0.12% of botanical composition of the west and south pastures,

respectively. Though present in the east pasture, it was not represented in the data collected.

Each of the six remaining species was represented in only one of the three pastures. Honey mesquite occurred only in the west pasture. Apache plume and mountain mahogany occurred sporadically in the south pasture. Pale wolfberry (Lycium pallidum), fourwing saltbush and ponderosa pine saplings occurred only in the east pasture.

Herbaceous Cover

Herbaceous vegetation was sampled in August and September of 1983 concurrently with sampling of woody species. Included in the herbaceous vegetation were grasses, forbs and half-shrubs.

The year 1983 in which vegetation sampling was conducted was considered a dry year with a total precipitation of 27.91 cm (Table 1). Dry conditions during the growing season did not allow grasses to grow and set seeds; consequently individual species identification was a difficult task.

The mean percentage grass cover for the three pastures was 47.71 and was significantly different among pastures (Table 4). The west pasture had the highest percent cover, 56.44, while the east pasture had the lowest, 40.28. Grass cover was not separated by species due to difficulty of identifying individual grasses based on vegetative characteristics alone. Groce and Pieper (1967) found that blue grama occurred and provided the greatest cover on all locations on the Fort Stanton Experimental Ranch. Its percent composition ranged between 79.9 and 55.3 for loamy and hill locations, respectively. Sideoats grama was second in abundance.

Table 4. Mean percentages of foliar herbaceous cover, litter and bare ground on the Fort Stanton Experimental Ranch.

	Pasture					
	West	East	South	Mean	RME	PR>F
Grass	56.44[a1]	40.28[b]	46.40[b]	47.71	9.17	0.0001
Forbs	8.81[a]	2.72[b]	10.44[a]	7.32	5.42	0.0005
Litter	11.66[b]	19.44[a]	13.69[b]	14.93	7.39	0.0131
Bare ground	23.09[c]	37.56[a]	29.47[b]	30.04	8.23	0.0001
Total Cover	65.25	43.0	56.84	55.03		

[1]Means in the same row followed by different letters are significantly different at 0.05 level of probability.

Forb species showed high variability in abundance and distribution among species. Frequent zeros in data for many species in many locations did not allow the use of analysis of variance to detect differences of individual species among locations.

The mean percentages for forbs and half-shrub cover differed among pastures (Table 4). The south pasture showed the highest forb cover of 10.44%, while the east pasture showed the lowest percent forb cover of 2.72.

The percent composition of the important forbs and half-shrubs of the ranch are shown in Table 5. They include broom snakeweed, trailing flelabane (Erigeron flagellaris), rattlesnake weed (Euphorbia albomarginata), buckwheat, western ragweed (Ambrosia psitoslachya), scarlet globemallow and bladder-pod. Carruth sagewort was the most abundant forb species on the Fort Stanton Experimental Ranch. It occurred on mesas and less hilly sites and constituted part of the blue grama community. Its mean botanical composition was 3.54% and it constituted 3.79, 0.56 and 6.28% composition of the west, east and south pastures, respectively.

As expected, the percent herbaceous ground cover showed an inverse relationship to percent woody plant cover. The west and east pastures showed highest and lowest percent herbaceous cover of 65.25 and 43.00 (Table 4) and lowest and highest woody plant cover of 21.49 and 30.49% (Table 2), respectively.

The mean percent litter and bare ground were 14.93 and 30.04, respectively, and they indicated a positive association with percent woody plant cover. The east and west pastures, respectively, showed

Table 5. Vegetative composition, in percent, by grasses, forbs and half-shrub species on the Fort Stanton Experimental Ranch.

	West	East	South	Mean
Grass	85.68	86.56	75.56	82.60
Artemisia carruthii	3.79	0.56	6.28	3.54
Gutierrezia sarothrae	2.53	1.69	3.38	2.53
Erigeron flagellaris	1.29	0.66	2.13	1.36
Euphorbia albomarginata	0.50	0.84	1.06	0.80
Eriogonum hieracifolium	0.35	1.31	0.75	0.80
Verbena bipinnatifida	0.32	0.88	1.09	0.76
Ambrosia psilostachya	0.91	0.19	0.66	0.59
Sphaeralcea coccinea	0.41	0.34	0.94	0.56
Lesquerella fendlera	0.35	0.38	0.56	0.43
Miscellaneous	3.87	6.59	7.59	6.03

the highest and lowest mean percent litter, bare ground, and woody plant species cover (Tables 2 and 4).

Mule Deer Food Habits

There is extensive literature on food habits of mule deer throughout its range, but only fourteen mule deer diet studies were reported for the Southwest (Severson and Medina 1984). Although specific results of these studies seldom agree, general patterns of mule deer food habits can be drawn. The reasons for this variability can be attributed to the methods used to collect data and to the diverse habitat of mule deer.

Microhistological technique used to determine seasonal food habits of mule deer indicated that browse was the major constituent of mule deer diet. Browse constituted 78.47% of the annual diet with six species constituting 74.4% of total diet composition (Table 6). Forbs and grasses comprised 19.67 and 1.9% of the diet, respectively (Figure 2). This result is comparable to findings of other researchers. Anderson et al. (1965) found browse, forbs and grasses comprised 70.2, 25.8 and 1.0% of mule deer diet, respectively. Boeker et al. (1972) and Hunt (1978), respectively, attributed 75 and 77% of mule deer diet to browse, 16 and 22% to forbs, and 2.2 and 1% to grasses.

Data on mule deer food habits exhibited no significant differences ($P>0.05$) among years or pastures for any major dietary component (Table 7). Seasonal differences were significant for most species except for wavyleaf oak, Apache plume, snakeweed, buckwheat and

Table 6. Mean annual percent composition of mule deer diet.

	Percent Composition	Mean Frequency[1]	Root MSE[2]	PR>F
Quercus undulata	24.02	62.07	17.01	0.0006
Juniperus spp.	19.97	51.69	21.14	0.0001
Rhus trilobata	12.08	31.23	17.38	0.0001
Pinus edulis	7.48	19.32	20.43	0.0001
Cercocarpus breviflorus	5.68	14.67	12.92	0.1804
Fallugia paradoxa	5.17	13.35	10.63	0.0059
Atriplex canescens	0.84	2.17	6.13	0.5589
Yucca glauca	0.48	1.25	4.04	0.0063
Miscellaneous shrubs	2.75	7.11	6.36	0.0001
Total Shrubs	78.47	202.86		
Eriogonum hieracifolium	3.33	8.60	4.45	0.8136
Brickelia grandiflora	2.36	6.11	4.31	0.0001
Artemisia caruthii	2.36	6.09	5.69	0.0464
Verbena bipinnatifida	2.33	6.03	4.73	0.0435
Sphaeralcea coccinea	2.38	5.88	3.33	0.0001
Melilotus officinalis	1.39	3.60	4.13	0.0001
Gutierrezia sarothrae	0.47	1.21	3.41	0.0001
Miscellaneous forbs	4.99	12.90	5.87	0.0113
Total Forbs	19.61	50.42		
Grass	2.00	5.16	2.99	0.8437

[1]Mean number of microscopic fields in which a species occurred during all sampling periods

[2]Mean square error

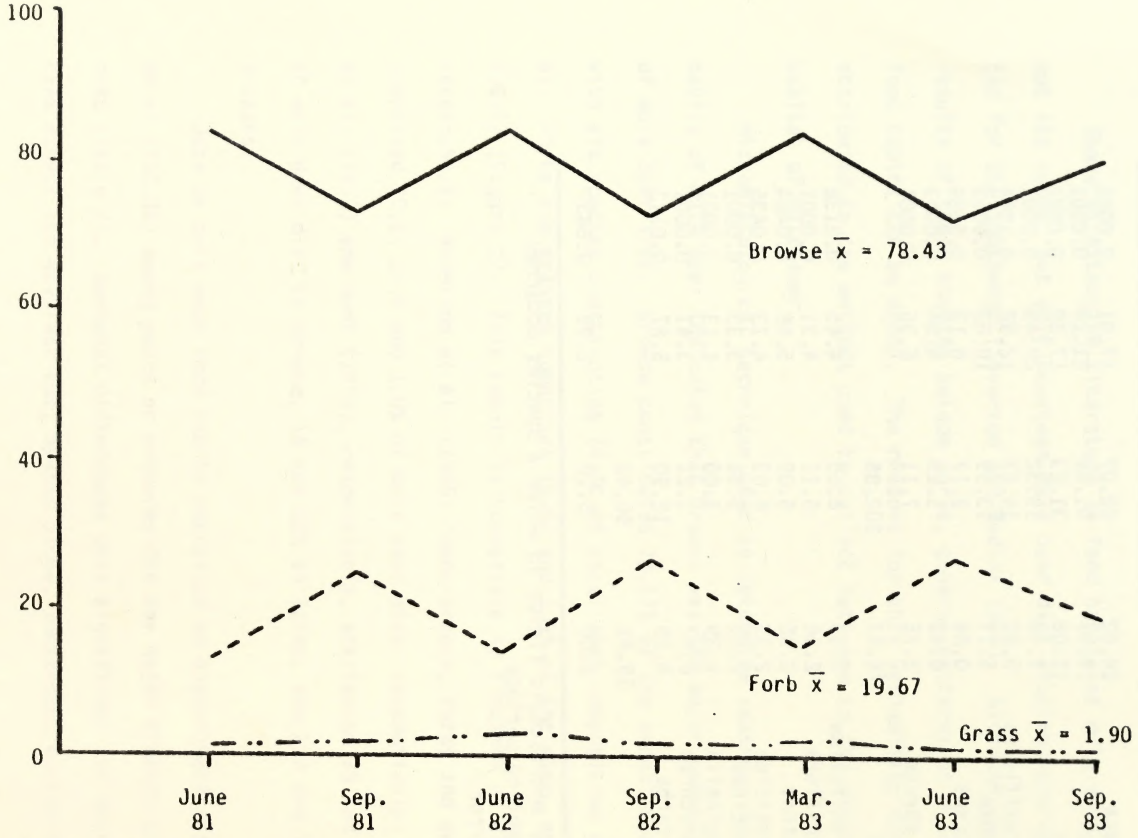

Figure 2. Browse, forb and grass content of mule deer diet.

yellow sweetclover (Table 7). Consequently, the seasonal diets are discussed separately in the following sections.

Spring Diets

Throughout the three years of the study, frequency of occurrence of deer pellets during the spring season was consistently higher in the west pasture, where a total of 36 transects had pellet groups compared to 19 and 29 pellet-group transects in the east and south pastures, respectively (Table 8). A total of 84 pellet samples were collected to represent three years of mule deer spring diet. Data indicated that browse, forbs and grasses constituted 84.14, 14.08 and 1.78% of the diet, respectively. Six browse species comprised about 80% of the diet and included juniper, wavyleaf oak, pinyon, skunkbush, mountain mahogany and Apache plume, in order of decreasing mean percent diet composition (Table 9).

Forbs constituted 14.08% of mule deer spring diet; the bulk of it was contributed by miscellaneous forbs. This catgegory contained 17 species and constituted 5.14% of the diet. Classified as miscellaneous forbs were unidentified forbs, half-shrubs, and identified species which constituted less than 1% of the diet. The rest of the forb component of the diet was comprised of four species. In order of decreasing composition, they were buckwheat, carruth sagewort, scarlet globemallow and vervain.

Grasses comprised 1.78% of mule deer spring diet with western wheatgrass as the major contributor. Cool-season grasses were the first herbaceous species to initiate growth and to provide green forage to herbivores after winter dormancy. The addition of

Table 7. Summary of the analysis of variance for selected botanical components of mule deer diet using type four sum of squares.

	SOURCE						
	Corrected Total	Year	Pasture	Year x Pasture	Season	Year x Season x Pasture	Error
Degrees of freedom	162	2	2	4	1	8	145
Species	Sum of Squares						
Juniperus spp.	95861	217	254	2108	18179*	4233	64833
Rhus trilobata	60785	1263	2455	970	4874*	3965	43797
Quercus undulata	55405	704	923	3467	1707	5864	41978
Fallugia paradoxa	20653	112	4	682	504	2300	16392
Cercocarpus breviflorus	27997	391	942	686	681*	846	24216
Pinus edulis	88379	709	1028	512	12415*	5091	60541
Gutierrezia sarothrae	2355	44	151	34	94	249	1691
Artemisia carruthii	5631	95	265	20	454*	175	4689
Eriogonum hieracifolium	3097	5	6	57	0	152	2866
Verbena bipinnatifida	3897	3	28	84	408*	91	3240
Brickellia grandiflora	8090	0	7	88	3804*	113	2689
Melilotus officinalis	5257	6	184	48	1382	267	2478
Sphaeralcea coccinea	2407	125	33	122	194*	149	1612
Grasses	1395	4	7	17	27*	24	1296

*P<0.05

Table 8. Frequency of occurrence of mule deer pellets on study transects.

	Spring				Summer			
Pasture	June 81	July 82	June 83	Total	Sept. 81	Sept. 82	Sept. 83	Total
West	13	15	8	36	15	14	12	41
East	4	11	4	19	7	2	3	12
South	11	10	8	29	10	9	7	26
Total	28	36	20	84	32	25	22	79

Table 9. Mean percent composition of mule deer diets during spring and summer seasons.

Species	Spring		Summer		
	Composition	Frequency[1]	Composition	Frequency	P>F[2]
Quercus undulata	22.08	56.23	25.18	63.81	0.1655
Juniperus spp.	24.75	63.01	15.10	38.23	0.0004
Rhus trilobata	10.02	25.53	15.13	38.34	0.0139
Pinus edulis	11.54	29.39	3.53	8.94	0.0022
Cercocarpus breviflorus	6.90	17.57	5.04	12.78	0.0348
Fallugia paradoxa	4.51	11.50	6.16	15.62	0.2221
Atriplex canescens	0.52	1.34	0.94	2.39	0.3547
Yucca glauca	0.78	1.99	0.00	0.00	0.0524
Miscellaneous browse	3.04	7.76	1.76	4.45	0.0999
Total Shrubs	84.14	214.32	72.84	184.56	
Eriogonum hieracifolium	3.34	8.52	3.35	8.50	0.9782
Brickellia grandiflora	0.23	0.61	4.71	11.93	0.0001
Artemisia carruthii	1.76	4.49	3.32	8.41	0.0019
Verbena bipinnatifida	1.70	4.35	3.18	8.06	0.0003
Sphaeralcea coccinea	1.74	4.45	2.76	1.00	0.0123
Melilotus officinalis	0.00	0.00	2.69	6.82	0.0002
Gutierrezia sarothrae	0.07	0.19	0.78	1.98	0.1197
Miscellaneous forbs	5.14	13.10	4.57	11.58	0.2151
Total Forbs	14.08	35.71	25.36	58.28	
Grasses	1.78	5.54	1.81	4.58	0.0183

[1]Mean number of microscopic fields in which a species occurs

[2]Comparisons between spring and summer seasons

immature grass, high in protein and water content, to the deer diet in early spring, was almost certainly a shock to the digestive system of the animal. Deer on poor ranges and showing symptoms of malnutrition apparently would not be physiologically able to stand the sudden change, and might die as a result (Dietz et al. 1962).

Anderson et al. (1965) analyzed stomach contents of mule deer in the Guadalupe Mountains of New Mexico. They found that spring diet consisted of 68.3% browse and 30.7% forbs. Wavyleaf oak, unidentified forbs and yucca were the most important components of mule deer spring diet and constituted 58.5%. Important forbs in spring diet included Acanthacae spurge, Euphorbia spp., Sphaeralcea spp., Stenandrium (Stenandrium barbatum) and Russian thistle (Salsola kali), each of which comprised less than 5% of the diet.

In Fort Bayard, New Mexico, mule deer diet during spring consisted of 30% forbs and 58% browse. Wavyleaf oak, mountain mahogany, Wright silktassel (Garrya wrightii), and skunkbush were the most important browse species (Boeker et al. 1972).

Boeker et al. (1972) found that use of individual species of forbs varied with season according to availability. Species used only during spring included buffalogourd (Cucurbita foetidissima), tansy mustard (Descurainia pinnata), loco (Astragalus spp.), buckwheat, Dalea spp. and bundleflower (Desmanthus cooleyi).

Using a bite count technique, Hunt (1978) found that mule deer spring diet consisted of 91% browse, 4% forbs and 1% grasses. Mountain mahogany and gray oak (Quercus grisea) comprised 60 and 30% of the diet, respectively. Of 25 forb species sampled, 4 occurred only

during spring. These species were monkey flower (Mimulus guttatus), sour dock (Rumex hymenosepalus), goat's beard (Tragopon dubius) and scrambled eggs (Corydalis aurea). Among the first species to initiate green growth and provide green forage were desert verbena (Verbena wrightii), resin weed (Viguiera multiflora), globemallow, scrambled eggs and annual grasses.

Summer Diet

The trend of frequency of occurrence of deer pellets during summer was similar to that observed during spring. The west and east pastures showed the highest and the lowest numbers of pellet-group transects containing deer pellets, respectively (Table 8). A total of 79 pellet samples were collected to represent three years of summer mule deer diets. Data indicated that browse, forbs and grasses comprised 72.84, 25.35 and 1.81%, respectively. The six browse species which constituted the bulk of the spring diet were major components of summer diets and comprised 70.14% (Table 9). In order of decreasing percent composition, they included wavyleaf oak, skunkbush, juniper, Apache plume, mountain mahogany and pinyon. Wavyleaf oak replaced juniper as the major component of the diet because of the decline in juniper content of the diet from spring to summer. Juniper, pinyon and mountain mahogany showed a significant decrease from spring diet. Skunkbush was the only browse species that showed a significant increase during summer (Table 9). This could be attributed to availability of leaves and new growth of tender twigs.

Forbs comprised 20.79% of the mule deer summer diet. The miscellaneous category, the major contributor, contained 24 species and comprised 4.57% of the diet. Six major species in order of decreasing percent diet composition (brickellia, buckwheat, carruth sagewort, vervain, scarlet globemallow and yellow sweet clover) constituted 20% of the diet. All except for buckwheat showed significantly higher values in the diet during summer compared to spring. Yellow sweet clover, though not represented in the diet during spring, constituted 2.69% composition of summer diet.

Grasses were significantly higher during summer, and they constituted 1.81% of mule deer diet with blue grama and vine mesquite as the main contributors.

Anderson et al. (1965) found that mule deer summer diet was composed of 62% browse and 33.7% forbs. Wavyleaf oak, unidentified forbs, skunkbush and juniper were the most important components of spring diet and constituted 57.4%. Important forbs included ring hair (Dyssodia papposa), Euphorbia spp., clover (Trifolium spp.) and desert verbena, which constituted 6.3, 5.1, 2.2 and 1.6% composition of mule deer summer diet, respectively.

Boeker et al. (1972) reported an increase in forb components of mule deer diet from 30% in spring to 42% in summer. Important forb species included fendler groundcherry (Physalis fendleri), day flower (Commelina dianthifolia), common purslane (Portulaca oleracea), morning glory (Ipomea spp.), spurge, dalea and bundleflower. Though forbs were slightly substituted for a portion of the browse, the browse components of the spring diet were comparable to those of summer.

Hunt (1978) attributed 60% of mule deer summer diet to forbs and 38% to browse. Mountain mahogany and gray oak contributed 32 and 3%, respectively. Important forbs included dalea, morning glory, birds bill dayflower and James' bundleflower, and they constituted 24, 8, 6, and 6% of mule deer summer diet, respectively.

Fall and Winter Diets

Due to heavy snowfall in December of 1982, pellet group collection was cancelled for that month. Pellets were collected in March of 1983 to represent those deposited during fall 1982 and winter 1983. Thirty-one pellet-group transects contained deer pellets in March of 1983. Of these, 15 occurred on the west pasture and 8 each occurred on the east and south pastures. Data for fall and winter diet determination did not lend themselves to statistical analysis since they were collected only once throughout the study period. Data indicated that browse, forbs and grasses constituted 80.9, 18.85 and 1.08% of mule deer diet, respectively (Table 10). Wavyleaf oak and juniper were the most important browse species and they constituted 20.86 and 10.19% composition of the diet, respectively. An observable difference from summer and spring browse components was an increase in fourwing saltbush and yucca. Forbs constituted 18.83% of the diet. Snakeweed showed its highest representation in the diet during this sampling period. It constituted 1.79% compared to 0.07 and 0.78% during spring and summer, respectively. No large variation existed between the seven components of the forb category of the diet (Table 10). This might be attributed to the six months' time lapse between the two pellet collections.

Table 10. Mean percent composition of mule deer diets during fall and winter.

Species	Percent Composition	Mean Frequency
Quercus undulata	20.86	57.71
Juniperus spp.	20.19	55.84
Rhus trilobata	13.73	37.87
Pinus edulis	5.38	14.32
Cercocarpus breviflorus	5.78	15.77
Fallugia paradox	4.72	13.48
Atriplex canescens	3.34	8.65
Yucca glauca	2.10	5.84
Miscellaneous browse	3.99	11.52
Browse Total	80.09	221.00
Eriogonum hieracifolium	2.16	5.87
Brickelia grandiflora	2.44	6.68
Artemisia carruthii	2.50	6.87
Verbena bipinnatifida	2.54	7.00
Sphaeralcea coccinea	2.89	8.03
Melilotus officinalis	2.08	5.90
Gutierrezia sarothrae	1.79	5.16
Miscellaneous forbs	2.45	6.61
Forb Total	18.85	52.12
Grasses	1.08	2.97

Anderson et al. (1965) reported that browse constituted 80.4 and 71.2% composition of mule deer diet during winter and fall respectively. Juniper, yucca and mountain mahogany were important species during winter. Important food items during fall included wavyleaf oak, mountain mahogany, flax (Linum spp.) and juniper. Forbs composed 16.5% of the diet during winter and 28.4% during fall. Important winter forbs included unidentified species, flax and tickseed (Coreopsis tinctoria). Fall species included unidentified forbs, flax, lichen and black-foot (Melampodium leucanthum).

Boeker et al. (1972) found that browse composed 86% of mule deer diet during fall and 94% during winter. Important browse species during fall and winter included mountain mahogany, wavyleaf oak and Wright silktassel. Skunkbush was not used during winter when leaves were not available, but comprised 3-8% of the diet during other seasons of the year.

Hunt (1978) found that mountain mahogany and gray oak were the major contributors to browse components of the diet during fall (75%). Forbs constituted 25% of the fall diet. Herbaceous species used during fall included white sweet clover (Melilotus albus), dalea, deer vetch (Lotus wrightii), resin-weed (Viguiera cordiflora), bahia (Bahia dissecta), and brickellia. Two browse species were important in the winter diet. Mountain mahogany and gray oak constituted 64 and 31% of mule deer winter diet, respectively. Herbaceous species represented in winter diet included bahia, wild buckwheat (Eriogonum wrightii), wood sunflower (Helianthella quinquenervis), sage (Salvia reflexa) and mullein (Verbascum thapsus).

Important Dietary Species

Diet selectivity is a major concern in all nutritional studies. Dietz et al. (1958) and Anderson et al. (1965) indicated that tender parts of green, growing plants offered higher food values per unit of volume for deer than mature plants and that deer tended to select nutritious, highly digestible plants and plant parts. McCulloch and Urness (1973) found that leaves were important in deer diet, and so little stem and twig material was found in deer rumen that only leaves were used in the calculation of dietary intake. Hunt (1978) observed that deer preferred a specific part of each species and that preference shifted as season and phenology of the plant progressed. Fungi and fruits of certain plants were actively sought and heavily used when available. Mule deer, by having low total forage demands, small rumen-volume-to-body-weight ratio, and high nutrient requirements per unit body weight must consume highly nutritious diets to meet their nutritional needs (Hanley 1982).

Wavyleaf oak. Wavyleaf oak is an important browse species for big game and livestock. Its mean percent composition on Fort Stanton pastures was 41.3 and there were no significant differences in percent cover among pastures (Table 2). Pfister et al. (1984) noticed that wavyleaf oak occupied dense stands along canyon slopes and upper rims, and was browsed voraciously by cattle at times. Dietary content of wavyleaf oak was related to its ease of prehension and immediate availability.

Wavyleaf oak was also the largest contributor to mule deer diets in this study. It was a stable food source that exhibited no

significant differences among years, pastures or seasons (Table 7). Anderson et al. (1965) found that wavyleaf oak was the largest contributor to mule deer diet on the Guadalupe Mountains in southeastern New Mexico. Hunt (1978) found that gray oak was the second-largest contributor to mule deer diet at Fort Baryard. Its representation in the diet fluctuated greatly throughout the year following availability of acorns. Mule deer spent considerable time involved in an active search for acorns through the stems and leaf clusters. Occasionally a leaf cluster would break off and be eaten along with an acorn.

Although wavyleaf oak contributed the greatest amount of any species to both diets and vegetational cover (Table 11), it was not as important in the diet as it was in the vegetation. The species contributed over 40% to the plant cover but less than 25% to the annual deer diets. This indicates that wavyleaf oak is not particularly preferred, but might be eaten simply because it is very abundant. It was somewhat surprising that wavyleaf oak was not preferred during the spring when early leader growth and leaf formation occurred. However, there were no differences ($P>0.05$) in dietary oak content between seasons.

Cordova (1974) determined the nutrient contents, IVDMD and IVOMD of wavyleaf oak on the Fort Stanton Experimental Ranch. He found that ash content was 5.30%, crude protein 15.67%, ether extract 3.13%, ADF 29.33%, ADL 9.00%, phosphorus 0.26%, IVDMD 52.00% and IVOMD 49.00%. These data indicated that wavyleaf oak is a nutritious browse species. Its main disadvantage was low

Table 11. Mean percent annual dietary and botanical composition of important plant species on Fort Stanton.

Species	Dietary Composition	Botanical Composition
Quercus undulata	24.02	41.30
Juniperus spp.	19.97	31.52
Rhus trilobata	12.08	0.91
Pinus edulis	7.48	19.91
Cercocarpus breviflorus	5.68	0.04
Fallugia paradoxa	5.17	0.12
Eriogonum hieracifolium	3.33	0.80
Artemisia carruthii	2.36	3.54
Verbena bipinnatifida	2.33	0.76
Sphaeralcea coccinea	2.28	0.56
Gutierrezia sarothrae	0.47	3.54

digestibility, which would affect availability of nutrients to the animal and might have affected representation of plant fragments in the feces.

Juniper. Two species of juniper, one-seed juniper and alligator juniper, existed sympatrically on the Fort Stanton Experimental Ranch. They occupied pinyon-juniper woodland habitat that dominated the slopes and rocky ridges. Junipers were the second-largest contributors to mule deer diet. Their representation in the diet was consistent among years and pastures; however, spring diets exhibited significantly higher values. Similar findings were reported by Anderson et al. (1965) who could not differentiate between Juniperus spp. in deer rumen. They found that these two species were the second-largest contributors to mule deer diet in the Guadalupe Mountains. Hunt (1978), using a bite-count technique near Silver City, N.M., was able to observe mule deer browsing alligator juniper while rejecting one-seed juniper. Deer were also observed bedding under large alligator juniper trees, where relatively soft bedding and few low branches did not limit bedding area or obstruct the animal's vision.

No analysis of juniper nutrient content has been conducted on the Fort Stanton Experimental Ranch. Smith (1957) found crude protein of Utah juniper (Juniperus utahensis) was 6.2% with a digestion coefficient of 16.8%. Ether extract was 14.1%. However, part of the ether extract was composed of volatile oils. These oils disappeared during the process of digestion, but may not be assimilated by the animals. He concluded that juniper constituted a poor winter

forage. Dietz et al. (1962) reported that the lowest level of nutrients in plants occurred with the peak of winter use. They found that protein content of juniper was just above the 5% figure given by Einarsen (1946) as minimal for deer maintenance. Juniper was very high in fat content, which might be indigestible and actually detrimental to ruminant animals. Low digestibility (Smith 1957) of juniper may have contributed to some degree of overestimation in diets as determined from fecal analysis. Juniper was also more abundant in the vegetation than in the diets.

Mountain mahogany. Mountain mahogany was an important browse species that constituted only 0.04% of woody species composition on the Fort Stanton Experimental Ranch. Though it occurred in low numbers in all three pastures, it was only encountered when sampling the south pasture.

Mountain mahogany contributed 5.7% of the plant composition in the mule deer diets (Table 11). No significant differences existed among years, pastures or their interactions. However, mule deer diet in spring had a significantly higher representaiton of mountain mahogany. Thus it appears that consumption of mountain mahogany was limited by availability. It appears to be rather palatable.

Anderson et al. (1965), using rumen content analysis, found that mountain mahogany constituted 11.9% of mule deer diets. Hunt (1978) attributed 55% of mule deer diets to mountain mahogany. However, it is much more abundant at Fort Bayard than at Fort Stanton.

Smith (1957) found that crude protein content of mountain mahogany was 7.2% with a digestion coefficient of 48.5. Ether extract

constituted 4.5% with a digestion coefficient of 37.6. Dietz et al. (1962) reported that crude protein content of mountain mahogany in peak winter was 8.2%, and he noticed an increase in nutrient content with increased elevation. In southern New Mexico, nutrient content of mountain mahogany was studied by Cordova (1974) and Mahgoub and Pieper (1982). Cordova (1974) found ash content of mountain mahogany was 6.2%, crude protein 15.6%, ether extract 4.2%, ADF 26.0%, ADL 11.8%, IVDMD 60.7%, and IVOMD 58.7%. Mahgoub and Pieper (1982) found mountain mahogany leaves were significantly higher in nutrients and digestibility than stems. Since mountain mahogany was evergreen and deer were selective for leaves (McCulloch and Urness 1973), it could be concluded that mountain mahogany could provide a valuable food source during the winter. The main constraint in the Sacramento Mountains was that mountain mahogany constituted only 0.04% of woody plant composition in the area.

Apache plume. Apache plume was present throughout the entire study area, but was represented only in the data collected from the south pasture where it constituted 0.12% of woody plant species composition (Table 11). The mean percent composition of Apache plume in mule deer diet was 5.2%. Its use was consistent across years, pastures, the year x pasture interaction, and seasons. Anderson et al. (1965) found Apache plume constituted 0.9% composition of mule deer diet. The highest representation in the diet occurred during spring. Cordova (1974) determined chemical composition of Apache plume in Fort Stanton. He found that its ash content was 6.0%,

crude protein 14.9%, ether extract 4.4%, ADF 22.9%, ADL 6.2%, phosphorus 0.25%, IVDMD 59% and IVOMD 57.3%.

Carruth sagewort. Carruth sagewort was the most abundant forb on the Fort Stanton Experimental Ranch and it constituted 3.54% composition of herbaceous species (Table 5). It was highly preferred by cattle (Pfister et al. 1984), but constituted only 2.36% composition of mule deer diet. Contribution of carruth sagewort to mule deer diet was consistent among years and year x pasture interaction. However, significant differences existed among pastures and between seasons. Diet of mule deer on the south pasture was significantly higher in carruth sagewort than that of deer on the west pasture. Summer diets showed significantly higher representation of carruth sagewort in the diet than spring. However, there was no marked preference for carruth sagewort by mule deer.

Vervain. Vervain constituted 0.76% composition of herbaceous species and contributed 2.33% to mule deer. Representation of vervain in the diet was consistent among years, pastures, and year x pasture interaction; however, inconsistency existed between seasons. The diet of mule deer during summer was significantly higher in vervain than that of spring. Anderson et al. (1965) found that vervain constituted 0.6% of mule deer diet and showed highest representation during summer. Vervain was present in greater proportions in the diet than in the vegetational cover (Table 11), and was probably limited in the diet by availability.

Scarlet globemallow. Scarlet globemallow was an important forb that constituted 0.56% composition of herbaceous vegetation. It was highly preferred by cattle (Pfister et al. 1984), and constituted 2.28% of mule deer diet. The contribution of scarlet globemallow to the diet of mule deer was consistent among years, pastures, and year x pasture interaction. Significant differences existed between seasons, with summer having higher values of scarlet globemallow in the diet. Anderson et al. (1965) reported that scarlet globemallow constituted 0.7% of mule deer diet with highest representation occurring during spring.

Chemical Composition

The nturient contents of carruth sagewort, vervain and scarlet globemallow on the Fort Stanton Experimental Ranch were determined by Cordova (1974). He found that forbs contained more ash than browse; however, that might have been attributed to soil contamination. Vervain and carruth sagewort showed the highest and lowest ash contents; 13.2 and 8.9%, respectively. Crude protein content of forbs was less than that of browse and it decreased at a faster rate as the season progressed. Scarlet globemallow showed crude protein content of 14.3%, carruth sagewort 12.9%, and vervain 12.0%. Forbs contained higher ether extract than browse and that was attributed to high ether extract in carruth sagewort, which was the highest of all the forages Cordova collected. Forbs contained higher ADF, higher IVOMD and lower ADL than browse. Significant differences existed among forbs in digestibility, with vervain being the most

digestible (77%), scarlet globemallow the least (60%), and carruth sagewort intermediate (67%).

Accuracy of the Estimates

Six artificially made mixtures were analyzed to determine familiarity of the author with diagnostic characters of important plant species in mule deer diet and to help establish his accuracy in estimating different dietary components (Appendix Table 12). Though no statistical analysis was performed on the data, Kulcyznski's formula (Oosting 1965) was used to evaluate similarity between actual and estimated undigested components of the mixtures. Results indicated that similarity indices of the six mixtures consecutively were 93.2, 92.3, 95.4, 96.6, 93.7 and 88.5%. The mean similarity index for the six mixtures was 93.3%. Stephenson (1982) and Jeffers and Holechek (1984) conducted similar studies and obtained similarity indices of 77 and 85%, respectively, between actual and estimated mixtures.

There has been inconsistency among researchers in assessment of the accuracy of microhistological estimates. Studies conducted by Voth and Black (1973), Westoby et al. (1976), Smith and Shandruk (1979), McInnis et al. (1983), and Gill et al. (1983) indicated inaccuracy of microhistological analysis in assessment of diets which contained a high proportion of forbs and/or shrubs. This inaccuracy was attributed to differential digestibility (Dearden et al. 1975, Vavra and Holechek 1980) and fragmentation of different plant species after ingestion (Havstad and Donart 1978). To compensate for over- or underestimation of certain dietary components,

correction factors based on in situ or in vitro digestion were developed from regression equations (Dearden et al. 1975, Vavra and Holechek 1980). However, Sidahmed et al. (1981) and Gill et al. (1983) indicated that correction factors based on in situ or in vitro techniques were not suitable to adjust fecal analysis data for differential digestion. Jeffers and Holechek (1984) found that in vitro digestion had no influence on the accuracy of microhistological estimates. Their findings were consistent with those of Todd and Hansen (1973), Hansen et al. (1973), Stephenson (1982), and Johnson and Wofford (1982). Jeffers and Holechek (1984) attributed the lack of digestion influence to well-trained analysts using a higher level of magnification than the standard 100X.

Important browse species on the Fort Stanton Experimental Ranch included two deciduous shrubs, skunkbush and wavyleaf oak. McCulloch and Urness (1973) indicated that deer were more selective for leaves. However, when leaves were not available, they tended to select for younger photosynthesizing tissues within the woody material which usually contained more diagnostic characters than older growth.

Westoby et al. (1976), Holechek et al. (1982) and Gross et al. (1983) reported that technician error was the most important source of error in microhistological analysis. Johnson and Paerson (1981) stated that "microscopic analysis of botanical composition is as much an art as it is a science. Technicians must be trained in a program designed to build their confidence and skill for accurately quantifying composition of mixtures." Though Jeffers and Holechek

(1984) stated that similarity between actual and estimated mixtures were lower than those between digested and undigest mixtures, a value of 93.3% was obtained for the former in this study.

It could be stated that microhistological techniques used in this study provided an accurate estimate of mule deer diet. However, the study's design and the sampling technique adopted did not allow for detection of differences in dietary components within seasons.

Habitat Evaluation

Data from this study, as well as earlier studies (Wood et al. 1978), indicated that mule deer densities were higher in the west pasture than in the south or east pastures. If deer density can be used as an index to habitat quality, these data would indicate deer habitat was of higher quality in the west pasture than in the other two pastures. Cover of wavyleaf oak and juniper was lower in the west pasture than in the other pastures, but only at fairly high probability levels ($P>0.18$ for wavyleaf oak and 0.08 for juniper). Grass cover was also significantly ($P<0.05$) higher in the west pasture than in the other pastures, but other herbaceous components were not consistent among the three pastures.

Even if there were vegetation differences among pastures, apparently food resources were not different. There were no differences in dietary content of mule deer among the three pastures. Other habitat features such as topography, water availability, cover dispersion, etc. must be responsible for differences in habitat quality.

Pinyon-juniper control has been a common practice in the Southwest to improve conditions for livestock and game. Studies on Fort Stanton indicated that skunkbush cover may increase following cabling (Rippel et al. 1983). Increases in skunkbush may indicate improvement in deer food resources since it is apparently a preferred browse species.

There was no response of wavyleaf oak to the cabling on Fort Stanton, but there was response on other sites in the Sacramento Mountains (Schott 1984). The role played by wavyleaf oak in mule deer habitat is not clear.

Data from this study indicates that these habitats are not limited by food resources since the two most abundant dietary species were the most abundant species in the vegetaiton. Earlier studies have evaluated the importance of drinking water (Wood et al. 1978), but other habitat characteristics have not been studied completely.

SUMMARY

Browse and herbaceous species were sampled on the Fort Stanton Experimental Ranch. Their cover, composition and distribution were determined in deer habitat in the three main pastures that constitute the ranch. Eight browse species were represented in all three pastures and composed 99% of the total woody plant composition. Analysis of variance indicated that no significant differences existed among mean percent cover for each species. One hundred sixty-three pellet-group transects contained deer pellets during spring and summer seasons. Eighty of these occurred in the west and south pastures. The west and south pastures also showed higher percentage herbaceous cover and significantly higher percentages of forbs than the east pasture. Wood et al. (1978) associated the use of the range by mule deer with presence of water and higher diversity of browse species.

Microhistological techniques were used to determine seasonal food habits of mule deer on the Fort Stanton Experimental Ranch. Data indicated that mule deer subsisted on a diet dominated by browse species, of which wavyleaf oak and juniper were the most important, mainly because of availability. Forbs supplemented the browse diet when they were available during years of favorable summer and spring rainfall. Though the technique identified important plant species, it could not detect use on fruits and mushrooms, and the sampling procedure did not allow detection of differences in dietary components within seasons.

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APPENDIX

Appendix Table 12. Actual (A) and estimated (B) botanical composition of six artificially compounded mixtures.

Plant Species	Compounded Mixtures											
	1		2		3		4		5		6	
	A	B	A	B	A	B	A	B	A	B	A	B
Agropyron smithii	10.0	9.1	10.0	9.6								
Bouteloua gracilis	30.0	28.6	10.0	9.6	5.0	4.8			6.6	7.2		
Lycurus phleoides	10.0	12.2	10.0	10.5	5.0	5.1			6.6	9.3		
Panicum obtusum	10.0	11.8	30.0	26.5	5.0	4.1	10.0	8.0			5.0	3.3
Total Grasses	60.0	61.7	60.0	56.2	15.0	14.0	10.0	8.0	13.2	16.5	5.0	3.3
Artemisia carruthii			10.0	13.8	10.0	11.3						
Brickellia grandiflora	5.0	3.5			10.0	11.0						
Eriogonum hieracifolium	5.0	5.2			10.0	10.3	20.0	21.0				
Melilotus officinalis	5.0	4.2			10.0	8.2						
Sphaeralcea coccinea			10.0	11.5	10.0	8.6	40.0	41.5				
Verbena bipinnatifida	5.0	4.5			10.0	9.9			33.3	32.0		
Total Forbs	20.0	17.4	20.0	25.3	60.0	59.3	60.0	62.5	33.3	32.0		
Atriplex canescens	5.0	4.5					5.0	3.6	44.4	47.4		
Ceratoides lanata			5.0	6.1							30.0	34.6
Cercocarpus breviflorus			5.0	6.1							30.0	32.2
Fallugia paradoxa	5.0	6.3			10.0	11.3						
Gutierrezia sarothrae			5.0	2.9					9.1	4.1		
Juniperus monosperma					5.0	5.1					15.0	18.5
Opuntia polyacantha	5.0	3.8										
Pinus edulis					5.0	4.8					15.0	5.2
Quercus undulata	5.0	6.3					25.0	25.9			5.0	6.2
Rhus trilobata			5.0	3.8								
Yucca glauca					5.0	5.5						
Total	20.0	20.9	20.0	18.5	25.0	26.7	30.0	29.5	53.5	51.5	95.0	96.7

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